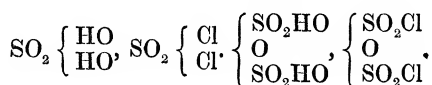
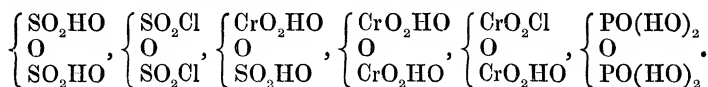


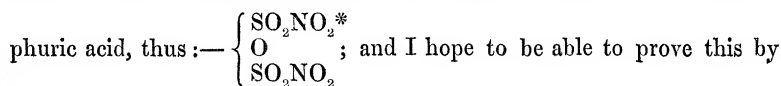
being the chloride of pyrosulphuric acid (so-called Nordhausen), to which it bears the same relation as sulphuric chloride to sulphuric acid,—



The old view of considering Nordhausen sulphuric acid as merely a solution of sulphuric anhydride in ordinary sulphuric acid has now probably but few partisans among chemists, it being looked upon as a true chemical compound, although of a very unstable nature, for the reason that on one side definite (sodic and potassic) salts of it are known, and on the other it presents analogies with certain chromium and phosphorus compounds, in which groups we are acquainted with the following series:—



The peculiar crystalline compound which plays an important part in the sulphuric-acid manufacture is also very possibly a derivative of pyrosulphuric acid, thus:—



the action of sulphuric anhydride on $\text{CH}(\text{NO}_2)_3$ or $\text{C}(\text{NO}_2)_4$.

IV. "On some of the more important Physiological Changes induced in the Human Economy by change of Climate, as from Temperate to Tropical, and the reverse." By ALEXANDER RATTRAY, M.D. (Edinb.), Surgeon R.N., H.M.S. 'Bristol.' Communicated by GEORGE BUSK, F.R.S. Received May 3, 1870.

Besides its obvious bearing on the long-vexed and still unsettled question of the unity of the human species, and on the closely related one of acclimatization, the present inquiry is of great medical importance. Tropical pathology, whether of native or foreign races, cannot be fairly studied until we thoroughly know its physiology; nor can we recognize and properly estimate disturbed action of organs till we understand their healthy functions. Otherwise natural phenomena may be mistaken for symptoms of sickness. Many so-called tropical diseases are merely exaggerations of the ordinary effects of climate, physiological merged into pathological phenomena; a knowledge of the one is the first step to an accurate acquaintance with and philosophical method of treating or preventing the other.

No inconsiderable part of our present knowledge of the vital phenomena

induced in the human economy in passing from cold to warm regions, or the reverse, is derived from experiments carried out in artificially made or seldom encountered climates. By hot-air chambers we illustrate the effects of augmented temperature on the respiration, pulse, &c., and by the rarefied atmosphere of mountain-tops show how diminished density acts. Neither of these, however, are fair examples of natural climates. Thus the former, dry and warm, is unlike the tropics, with its triple combination of increased heat, rarefied air, and excessive moisture; as the latter, dry and chilly, is dissimilar from the usual surface-climates of extra-tropical latitudes, which conjoin cold, condensation, and moisture. The dry and warm, or dry and cold, climates which occur in nature are usually local and limited. Nor do such abrupt and temporary exposures to heat and cold have any parallel in ordinary life, or are they likely to induce results similar to the comparatively slow transition involved in an ordinary change of climate; and though the rarefied air of heated chambers will decrease, while that of great altitudes will accelerate respiration, the former will do so less, and the latter more, than they otherwise would, from the skin, and especially the more slowly acting liver and kidneys, being unable at once to increase their action so as to aid the lungs in eliminating carbon. The functional changes so induced cannot therefore be taken as a fair criterion of what occurs in nature; and as mere approximates to truth, such observations, though interesting, are evidently wanting in practical importance.

I. *The Influence of Tropical Climates on the Respiration.*

It has been ascertained, by the experiments already alluded to, that the respirations are diminished in frequency in warm and increased in cold air; but we do not yet know what happens in the tropics, where great heat, rarity of air, and moisture are conjoined. Nor has it yet been shown whether the quantity of air respired is greater in the tropics or less. It is obviously necessary to ascertain both before we can decide whether the total quantity of air and oxygen respired, and the amount of carbonic acid and watery vapour exhaled, be different or not.

The following experiment will show that the *capacity of the chest* for air is materially affected by tropical climates:—

TABLE I.—To show the effect of tropical weather on the capacity of the chest, as indicated by the spirometer.

		Age.	Height.	1. Temp. zone near England, at sea, June 23, 1869. Therm. 65° F. Hygr. 2½° F.	2. Tropics, lat. 13° N., at sea in equato- rial doldrums, July 12, 1869. Therm. 78° F. Hygr. 4° F.	3. Tropics, lat. 7° S., at sea in equato- rial doldrums, Aug. 20, 1869. Therm. 83° F. Hygr. 4° F.	4. Temp. zone, near England, at sea, Sept. 14, 1869. Therm. 65° F. Hygr. 1½° F.	5. Temp. zone, England, Plymouth, Feb. 10, 1870. Therm. 42° F. Hygr. 3° F.
			ft. in.	cub. ins.	cub. ins.	cub. ins.	cub. ins.	cub. ins.
Seamen (adult).	Wright *	25	5 11½	288	315	324	300	288
	Scaulan *	26	5 5½	222	255	254	240	236
	Rodd *	22	5 10½	303	327	327	300	288
	Bushell *	29	5 7	240	261	270	234	...
Officers (adult).	Maclean *	28	5 11	321	350	360	330	318
	Knott *	28	5 7½	219	243	246	234	...
	Ratray *	38	5 7½	219	246	258	234	224
	Norcott *	26	5 7½	216	240	246	231	215
	Carr *	25	6 0	256	294	303	258	255
	Browne *	26	5 11	285	316	318	276	274
	Walter *	27½	5 8½	267	285	300	270	252
	Symons *	34	5 9	237	237	243	216	213
	Turner	39	5 11	222	230	...	...	...
	Silver	31	5 6½	...	240	255	238	228
	Yesting	22	5 9	...	243	255	247	...
	Maude	22	6 3	...	...	288	252	...
	Haynes	23	5 8½	...	...	270	231	...
	Huyghue	50	5 4	...	198	198	180	...
Officers (cadets).	Fisher	16½	...	...	...	152	150	...
	Spencer	16½	...	...	...	162	140	...
	Malan	16½	...	...	...	153	149	...
	Collins	16½	...	...	...	180	165	...
	Simeon	16½	...	...	...	171	156	...
	Lees	16½	...	...	...	153	180	...
Average capacity of the								
12 marked *.		...	...	256.083	280.75	287.416	260.25	253.727
„ gain (by heat).		...	...	...	24.833	6.5833	...	...
					31.4163			
„ loss (by cold).		...	...	...	...	...	26.333	6.523
Percentage of gain in					12.24			
the tropics		...	...				...	...

This gives the results of observations with the spirometer on 24 healthy individuals, made during the voyage from England (lat. 51° N.) to Bahia (lat. 11° S.) and back. Four of these were strong, full-chested, adult seamen, fourteen healthy adult officers, and six young growing lads. In the twelve marked by an * the experiments were carried on throughout. Column 1 shows the capacity in the temperate climate of England during summer (June, average temperature 65° F., shade). The average of these twelve cases gives 256 cubic inches. Column 2 gives the capacity, nineteen days afterwards, in the equatorial doldrums and greatest heat (78° F., shade) of the outward voyage, and shows that this had increased to 280 cubic inches,

equal to an average gain of 24 cubic inches per man. Column 3 gives the capacity, thirty-eight days later, in the equatorial doldrums and highest temperature of the return voyage (83° F., shade), and shows that in ten of the twelve cases this increase was still further augmented by an average of $6\frac{1}{2}$ cubic inches from prolonged tropical exposure. It would be interesting to know the limits of this increase, and whether it is, as likely, permanent. The other two cases remained stationary. The total average in the twelve cases, during this fifty days' residence in the tropics, was 31 cubic inches (12·24 per cent.). In order to test whether this was due to climatic causes, or resulted from custom in using the instrument, the same cases were again tested about three weeks afterwards, on return to England in September, when it was found (column 4) that the capacity of the chest for air had again decreased in every case by an average of 26 cubic inches. Although the temperatures were identical (65° F., shade) on quitting and returning to England, the time was apparently too short to allow the capacity of the lungs to resume their first standard average of 256 cubic inches, being still at 260 cubic inches. But this result followed a subsequent reduction of temperature to 42° F. (shade) in February 1870, when the average capacity of eleven of the same cases was found to be 253 cubic inches, that is, 3 cubic inches below the first trial. This fact, however, goes far to prove that there is a limit to this reduction in the pneumatic capacity of the chest in health, which was probably nearly reached. The results among the other adults were identical, and showed that the capacity of the chest for air is considerably greater in the tropics than in temperate climates. This was noticeable in five of the six cadets. During the three weeks of the return voyage between the tropics and England, when from faulty diet their growth was nearly or altogether stopped, the capacity of the chest decreased considerably, when it might have been reasonably expected that the diminished capacity from climatic causes would have been more than counterbalanced by expansion from growth, usually very rapid at that age. This actually occurred in the sixth (Lees), a tall growing youth, in whom an increase of 27 cubic inches showed that his chest had enlarged considerably. The greatest increase in the pneumatic capacity of the chest from this sojourn in the tropics, of the twenty-four cases here recorded, amounted to 39 cubic inches, and the lowest to 21.

This and the subsequent experiments were made at sea, and in equable super-oceanic temperatures*. It will be interesting to know whether the same laws prevail in insular, littoral, and especially continental climates, possessing a higher day, lower night, and greater diurnal and annual range of the thermometer.

* The daily mean range of temperature, Fahrenheit, was:—

	Highest.	Lowest.	Range.
Extra-tropical	9°	1°	3°·63
Tropical.....	$6\frac{1}{2}$ °	1°	2°·9

the average for the entire voyage being 3°·2 F.

The following Table will show that the same law extends to the negro :—

TABLE II.—To show the effect of climate on the capacity of the chest in the black races.

Age &c.	Race.	Aug. 13, 1869. Lat. 8° S. Temp. 79° F.	Aug. 25, 1869. Lat. 16½° N. Temp. 78° F.	Feb. 12, 1870. England. Temp. 32° F.
		cub. ins.	cub. ins.	cub. ins.
Benjamin Campbell, æt. 21 Height 5 ft. 5½ ins.†	Negro of Sierra Leone	210	207	185
John Campbell, æt. 20 ... Height 5 ft. 4 ins.	Negro of Sierra Leone	174	166	156
John Williams, æt. 31 ... Height 5 ft. 4 ins.	Half caste	176	162	...

In the first case, a pure black, the capacity of whose chest amounted in the tropics to 210 cubic inches, it became reduced in the winter of England to 185 cubic inches. In the second, also a pure black, it fell from 174 in the tropics to 156 during the English winter. The 2nd column records the results of the exit from the doldrums into the trades,—the lungs of all races, and particularly those of the black tribes, being then supersensitive to even slight reductions of temperature.

That a similar decrease occurs in disease was shown in several invalids from Bahia with chest affections :—

TABLE III.—To show the influence of climate on the capacity of the chest for air in pulmonary disease.

Name &c.	Aug. 20, 1869, 3 P.M. Lat. 7° N.; calms of equator under sun; very sultry. Temp. 83° F.	Aug. 25, 1869, 3 P.M. Lat. 16½° N.; cool N.E. trades. Temp. 78° F.
	cub. ins.	cub. ins.
Abbott, æt. 22; phthisis, early 2nd stage ...	135	120
Cribbes, æt. 25; phthisis, 1st stage	148	140
Hughes, æt. 17; phthisis, 2nd stage	147	135
Ratford, æt. 25; phthisis, 2nd stage	96	84

Here, in all four cases, there was a decrease from 8 to 15 cubic inches, even in so brief an interval as five days, caused by the cool dry north-east trade-winds, suddenly met with after calm, moist, sultry weather near the equator. The period was evidently too brief, and the disease not sufficiently active in any of these cases, for this to have resulted from the formation or increase of cavities in the lungs; and it can only be ascribed to the law that the pneumatic capacity of the chest varies with temperature, increasing in tropical, and diminishing in temperate and cold climates.

A knowledge of this law is evidently of practical application in preventing mistakes in the spirometric diagnosis of certain lung-diseases. Thus the capacity of the chest of an individual debilitated by residence in the tropics, and weak-chested, but with no active lung-disease, being, say, 250

or 270 cubic inches, he might be supposed to have contracted incipient phthisis on reaching England in winter labouring under catarrh, with the pneumatic capacity of his chest reduced by from 25 to 35 cubic inches. On the other hand, a patient actually in incipient phthisis might be erroneously considered to have permanently recovered by a trip to the tropics having raised the capacity of his lungs for air by a similar amount, *i. e.* almost or actually up to the normal standard for his age and height in a temperate climate. A similar mistake might be made, especially if the instrument is carelessly used, in the same climate, *e. g.* that of England, at different seasons of the year, such as the height of summer and depth of winter, when a considerable difference in the capacity of the lungs for air must not be taken as an index of disease *. The greater the range between the summer and winter temperatures, the more marked will be the difference in the spirometric indications.

But it is not by deep inspirations like these that ordinary respiration is carried on; and it is important to ascertain whether the air inspired in each ordinary breath undergoes a similar increase and decrease according to climate. The difficulty in limiting and measuring the small quantity of air expired during our usual faint breathings makes this a far more delicate and difficult experiment than the preceding. From analogy, however, we may infer that it does vary; and the following will go far to prove it. My ordinary respirations ranged from 4 to 8, and averaged 6 cubic inches in a temperature of 44° F. (shade) during the winter of England. At Lisbon, during an average temperature of 65° F. (shade), they ranged from 5 to 13, and averaged 9 cubic inches†. Unfortunately while in the tropics I had not the proper apparatus to ascertain how much they increase during the far greater temperature of equatorial regions. As these results therefore only prove the existence of an increase, and do not show its extent, it will be necessary, as it is doubtless correct, to calculate the minor from the major increase.

The following Table will show the negative effect of period of the day on the capacity of the chest for air in the tropics.

TABLE IV.—The capacity of the chest for air, as influenced by period of the day in the tropics.

	In the Tropics, as a whole, 51 days.	Doldrums, or warmest part of the Tropics; average temperature 78½° F.
	cubic inches.	cubic inches.
9 A.M.....	244·3	243
3 P.M.....	244·42	242·57
9 P.M.....	245·06	243

* Table I. cols. 4 & 5.

† These amounts are all small, because those taken were the short ones which immediately follow the deep inspiration in which ordinary breathing usually culminates every twentieth or thirtieth inspiration.

Column 1 gives the average of the entire voyage, during which the equator was crossed and again recrossed. Here the results, morning, afternoon, and evening, both in the tropics generally and in its warmest part, the equatorial doldrums, are so very nearly identical that we may conclude that period of the day has very little influence on the capacity of the chest for air, or the power of taking deep inspirations.

Closely allied to the foregoing is the influence of tropical climates on the *frequency* of the respirations. In heated air-chambers respiration becomes less in man*. Vierordt and Ludwig also found that the respirations are lessened in number in animals subjected to heat†. Does this occur in natural tropical climates? We might infer that as the volume inspired increases, so does the number of respirations. But fact (Table V.) proves the reverse, and shows that, as in hot artificial climates, they are diminished in number.

TABLE V.—To show how the frequency of the respiration is affected by tropical climate.

		Average tempe- rature (shade).	Highest number of respi- rations.	Lowest number of respi- rations.	Average number of respi- rations.
Temperate Zone.	England, in summer (June)	Fahr. 62°	18	13·5	15·68
	„ in winter (8 Feb.)	42·25	17·5	15	16·5
Tropics ...	Equatorial doldrums (out- ward voyage)	78·74	14·5	11	12·74
	Equatorial doldrums (return voyage)	78·6	15	12	13·74

This Table is compiled chiefly from the daily results of a three months' voyage to Bahia and back, the observations being taken in the standing posture at 9 A.M., 3 P.M., and 9 P.M.; the averages are for a week. Thus in the summer of England, with an average temperature of 62° F., the average number of respirations per minute was $15\frac{2}{3}$; whereas in the doldrums, or warmest part of the tropics, during the outward voyage, with a temperature of 78 $\frac{3}{4}$ ° F., the average was only $12\frac{3}{4}$, and on the return voyage $13\frac{2}{3}$,—a decided decrease. In the winter of England (February), with a temperature of 42° F., the average had increased to $16\frac{1}{2}$, and at freezing-point (32° F.) to $17\frac{1}{2}$. With those results similar experiments carried out at my request by a colleague‡ coincided, and showed that though, as in temperate latitudes, the activity of the respiration differs in different individuals, they are diminished in number in the tropics. Thus, while his respirations averaged 16·077 per minute in the temperate climate of England (January, average temperature 32° to 44° F.), they average

* Parkes, 'Practical Hygiene'; Hooper, 'Physicians' Vade Mecum,' &c.

† Parkes, *ibid.*

‡ Mr. T. H. Knott, Assistant-Surgeon.

15·4 in the West Indies winter season (temperature 79° to 83° , shade) ; while, again, the sick-bay man's were 17·3 in England during winter, and 16 in the West Indies, my own were 17·5 in England, and 16·2 in the West Indies. The same may be noticed in an artificial climate of a heated room in England. Thus, while my respirations out of doors in a temperature of 30° F. were 17·5 per minute, they rose to 15·8 shortly afterwards by simply standing before a fire in a temperature of 57° F.

From these data we find that the increased quantity of air and oxygen inspired in the tropics does not make up for the diminished number of respirations in supplying the same amount of air and oxygen for blood-purification as in cold climates, though doubtless a requisite quantity is inspired, less probably being needed there, as will presently appear, to carry on the vital processes. Thus, taking the average number of respirations in the temperate climate of England at 17 (Table V.), and the quantity of air inspired each breath at 15 cubic inches, this would give 255 cubic inches per minute. Now if the chest (Table I.) gains in capacity by an average of 31 cubic inches (=12·24 per cent.) in the tropics, the gain on each ordinary respiration would be 1·836 cubic inch, thus raising the quantity inspired each breath to 16·836 cubic inches. The average number of respirations being taken at 14, this would give 235·704 cubic inches per minute, *i. e.* less by 19 cubic inches (8 per cent.) than in temperate climates ; equal to 1157·760 cubic inches per hour, or 27786·24 cubic inches per day. Thus—

	Cubic inches in each inspiration.		Number of respi- rations.		Cubic inches respired per minute.
England	15	×	17	=	255
Tropics	16·836	×	14	=	235·704

Difference in favour of a temperate climate 19·296 cub.in.(=7·567p.c.)

This decrease of 7·567 per cent. in the quantity of air respired daily diminishes the quantity of carbon which the lungs in ordinary circumstances can throw off in the tropics by 0·7567 oz., or rather more than $\frac{3}{4}$ oz. ; 10 ozs. being taken as the average amount thrown off in temperate climates*, will give 9·243 oz. as the amount for the tropics. But as tropic air contains less oxygen for a given bulk than air of colder latitudes, according to Dalton and Gay Lussac's law of expansion of gases by heat, the decarbonizing capabilities of the lungs in tropical latitudes will evidently be still further curtailed, and the amount of carbon they can throw off considerably decreased. Air increases by $\frac{1}{480}$ its volume for every Fahrenheit degree of heat ; and the difference between the temperatures in which these experiments were carried on being 18° F. (65° and 83° F.), if we reduce the amount inspired in the tropics by a $\frac{18}{480}$ part, this will give its equivalent bulk in the temperate zone. Thus,—

* Hooper, 'Physicians' Vade Mecum.' Mean of three estimates by Lavoisier and Seguin, Davy, and Allen and Pepys.

$$\frac{235 \cdot 704}{(1 + \frac{1}{450} \times 18)} = \frac{235 \cdot 704}{1 \cdot 0375} = 227 \cdot 1846 \text{ cubic inches,}$$

which is equal to a decrease of 8·5194 cubic inches or 3·614 per cent.; then 225—227·1846 cubic inches gives 27·8154 cubic inches per minute, or 1668·924 cubic inches per hour, or 40054·176 cubic inches per day = 10·907 per cent. as the grand total difference in favour of a temperate climate, after deducting the real decrease in volume, and correcting for expansion by heat. By again reducing the 9·243 oz. of carbon by 3·614 per cent., or 0·33409 oz., we get 8·909 oz. as the total amount which the lungs throw off in the tropics, the difference between the tropical and extra-tropical quantities being 1·1028 oz. This result in the human species accords with Vierordt's observation on the lower animals, viz. that less carbonic acid and presumably less water are eliminated when they are subjected to heat*. This, then, is probably the rule, but in exceptional cases, from idiosyncrasy, accelerated or forced respiration may make the quantity of carbon which the lungs can exhale in temperate and tropical regions more nearly alike.

Thus the relative proportions of carbon thrown off by the several depurating organs in the tropics differs from those of temperate latitudes. Hooper† gives the latter as:—lungs $10\frac{1}{2}$ oz., skin $\frac{1}{4}$ oz., fæces $\frac{1}{2}$ oz., urine $\frac{1}{2}$ oz., total $11\frac{3}{4}$ oz.; we have found that in the tropics the amount eliminated by the lungs is reduced by $1\frac{1}{4}$ oz. Under judicious hygienic, and especially dietetic management, that for the skin, liver, and urine may not be materially altered from these figures; but otherwise it is probably on the skin that the greatest share of its burden is thrown. We may presume that the liver-work and bile are increased, though perhaps only slightly, in the tropics, although this has not yet been actually proved. The kidneys may assist to a greater extent; for though the urine is diminished in quantity in the tropics, the relative amount of solids is not correspondingly altered. Much of the latter may be carbon; for though the urea eliminated by the kidneys in the tropics is diminished‡, the quantity of uric acid, which contains thrice the amount of carbon, has not yet been ascertained.

The mutual bearing of these two closely related but very opposite results, viz. an increase in the capacity of the chest for air in the tropics, with a decrease in the number of the respirations, is an interesting if not important study. Hasty inference might lead us to attempt to explain the former by a greater volume of the rarefied and moisture-laden air of the tropics being required to supply the system with the requisite quantity of oxygen. But there are several objections to this theory, *e. g.* :—

1. Nature might do this in health as she often does in disease, such as phthisis, pneumonia, &c., by increasing the frequency of the respirations,

* Parkes, 'Practical Hygiene,' 2nd edit.

† Physicians' Vade Mecum.

‡ Parkes, 'Practical Hygiene,' 2nd edit. p. 448.

whereas here they are diminished in number. To increase the one and diminish the other, the first implying augmented, and the second decreased energy in the respiratory muscles, implies an anomaly which it is unnecessary to accept when the phenomena can be otherwise and better explained.

2. External measurement, moreover, shows that there is actual increase in the capacity of the chest from its expansion by increased action by its inspiratory muscles. Thus in three adults in which the chest was measured by the spirometer and tape in the winter of England (average temperature 30° - 32° F.), and again at Lisbon (average temperature 60° F.), though in all three there was a decided increase in the capacity of the lungs for air to an average of 11 cubic inches, there was no perceptible increase in the circumference of the chest. In one case the latter had apparently decreased by one inch, as if from loss of muscular tone.

3. It is more than doubtful if the system actually requires an increased quantity of air or as much oxygen to carry on the vital processes in the tropics as in cold climates, and the above-mentioned data prove that it actually gets less of both. Less oxygen is required in the high temperatures of low latitudes, because the tissues generally decay less rapidly*. Owing to diminished mental and bodily exertion of the two which make up the bulk of the body, viz. the muscular and nervous, less is required for the metamorphosis of waste particles. Where a diminished necessity and desire for food lessen the ingesta, and judicious selection reduces the amount of carbon this contains, less oxygen is required for direct combination with the elements of the food to generate heat. Moreover it is certain that the increased absorption of oxygen by the functionally excited skin in the tropics, where it acts vicariously for the lungs as a respiratory organ, lessens materially the amount required by the lungs. Furthermore, the skin is aided in relieving the lungs in the decarbonizing process by the functionally excited liver and perhaps kidneys, which throw off the carbon in forms which do not require much oxygen for their formation, viz. as bile and uric acid.

The true explanation appears to be that there is really no actual increase in the capacity or size of the chest and enclosed lungs, but only an alteration in the relative proportion of blood and air contained in the latter†.

* Carpenter and others doubt this, and believe that they decay more rapidly; in other words, that when used there is a greater waste for the same amount of work. The sum total of this, however, for all the tissues will probably not be greater than the reduction due to the diminished amount of work which the principal tissues have to perform.

† With regard to the observation that the increased capacity for air in the chest is "only an alteration in the relative proportion of blood and air in the lungs," there must be a reservation made in favour of a statement (though it still, perhaps, has to be proved) that the bases of the lungs have a reserved capacity for air, any enlargement of which would, of course, have to be measured, not by expansion of the costal walls, but by protuberance of the abdomen, through encroachment on its cavity by

The bulk of the lungs remaining the same in the tropics as in colder latitudes, or being even somewhat diminished from their comparative abeyance as excreting and heat-generating organs, the blood, diverted to the functionally excited and congested skin and liver, permits the ingress of a larger quantity of air into the pulmonary air-cells and tubes; whereas in colder latitudes this is reversed, the lungs being more and the skin and liver less active; the blood drawn from the latter to the former diminishes the calibre of the air-vesicles and bronchi, lessening the quantity of contained air, as happens to a still greater extent in some lung-diseases, *e. g.* bronchitis, pneumonia, pulmonary congestion*, and phthisis, tubercle and not blood being in the latter the displacing agent. Briefly, the lungs (identical in size in both) contain less blood and more air in tropical than in temperate climates. The truth of the above explanation appears to be confirmed by facts noticeable in Table I., viz. that it is in thoroughly warm tropical regions, where the skin acts most freely and the sensible perspiration is most abundant, that the greatest difference is observable in the capacity of the lungs for air. Thus the difference between the capacity near the equator (temp. 83° F.) and September in England (temp. 65° F.) was 26 cubic inches; while between the latter and the winter of England (February, temp. 42° F.), when the functions of the skin were much more in abeyance, was no more than six cubic inches. And it corresponds with what Dr. Francis (Bengal Army)† has observed, viz. that the lungs are lighter after death in Europeans in India than the European standard. Parkes has made the same observation, and remarks that it shows apparently a *diminished respiratory function*.

A knowledge of this law, in addition to its diagnostic value, is evidently of considerable therapeutic importance as furnishing a guide to the rational treatment of many, and especially congestive or inflammatory diseases of the lungs. By its facts the true *rationale* of the benefit derived in the earlier stages of phthisis, or where it is merely imminent from a sojourn in a subtropical climate, is of easy explanation. Residence in a warm atmosphere is followed by a decrease in the quantity of blood in the affected lungs, by diminished activity in the vital processes carried on therein, by facilitated respiration, and, above all, by diminished lung-work from vicarious action of the physiologically excited skin and liver; while the inhalation of milder, more equable, and less irritant air diminishes the chances of excitement or increase of distressing local inflammation and

descent of the diaphragm; and the exceptional case above related of diminution of the costal circumference may possibly be explained by the diaphragm counteracting the other respiratory muscles, whilst unusually contracting in answer to the room required by this reserved power of the bases of the lungs being called into action.

* See an admirable letter on "Swimmer's Cramp" in the 'Lancet' for October 9, 1869, p. 531, by my friend Mr. Henry Hales of Reigate, who first suggested to me a satisfactory explanation of the above phenomena.

† Parkes, 'Practical Hygiene,' 2nd edit. p. 463.

those bronchial attacks so apt to break up old and cause the deposition of new tubercle. Might we not wisely imitate this oftener than we now do in practice? The increased pneumatic capacity of the chest indicates a decrease in the quantity or bulk of blood in the lungs equivalent to the increase in the quantity of air. If, for example, the latter is increased by 30 cubic inches, this implies a permanent withdrawal of 16·62 ounces of blood from the lungs to the skin and liver. Now if we can imitate Nature's operations, and, by increasing the temperature of a sick-room or ward in this the temperate climate of England, can convert it into a local subtropical or tropical climate, we withdraw no inconsiderable amount of blood from the lungs to the skin and liver, thus relieving its overburdened capillaries, permitting freer access of air, and so aiding the respiratory process—a safe and sure mode both of relieving dyspnoea and cough, and aiding the *vis medicatrix*.

In tropical hygiene the law appears equally suggestive. Is not the decrease in the quantity of carbon which the lungs can throw off, by $1\frac{1}{10}$ oz., an indication of the necessity for regulating the diet both as to quantity and kind, and especially of making it less carbonaceous? When this is attended to, and for other reasons already alluded to, the quantity of oxygen taken in by the lungs is sufficient to enable them to throw off their allotted portion of carbon. Even when the diet is unaltered, the functionally excited and vicariously acting skin, liver, and perhaps kidneys may be able to eliminate surplus carbon up to the above-mentioned amount, and perhaps a little beyond it. But this doubtless has a certain and probably individually varying limit; and from a prolonged and excessive ingestion of highly carbonaceous food in the tropics, all three organs are apt to suffer from overwork, as may also the lungs in endeavouring to aid them by accelerated and perhaps forced respirations. The importance of keeping the lungs, the great carbon-eliminator in all climates, and the skin, one of the chief in the tropics, in a state of the most perfect functional activity possible, especially in the tropics, will be equally apparent, as will also, in disease of any one of them, the indication with regard to the rest; and, considering the great importance of the skin in acting vicariously for the lungs as an eliminator both of carbonic acid and water, the necessity for constantly keeping it in healthy action during disease of the latter organs, especially phthisis, will appear imperative.

The following Table will show the relation of the frequency of the respirations to the period of the day in the tropics.

TABLE VI.—To contrast the number of respirations per minute (morning, afternoon, and evening) in tropical and extra-tropical latitudes.

	Extra-tropical, between lat. 50° and 26° N.; aver- age of 26 days.	Tropical, between lat. 32° N. and 13° S.; average of 53 days.
	Number per minute.	Number per minute.
Morning (9 A.M.)	North ... 14·19 } ... 13·99 South ... 13·8 }	13·15
Afternoon (3 P.M.)	North ... 16·34 } ... 15·74 South ... 14·75 }	13·65
Evening (9 P.M.)	North ... 16·30 } ... 15·68 South ... 15·06 }	14·18
Averages	15·07	13·66

Here two facts are apparent,—first, that the number of respirations (morning, afternoon, and evening) are all less than in temperate regions; and, second, what is more specially designed to prove, viz. that in tropical as in temperate latitudes the respiration is least frequent in the morning, and gradually increases as the day advances. Thus at 9 A.M. it was 13·15, at 3 P.M. 13·65, and at 9 P.M. 14·18. The Table further appears to indicate that the difference between the number of morning and evening respirations is not so great in the tropics as in colder latitudes. In the former the lungs play a less active part as a heat-generator and eliminator of carbonic acid and water. Hence the respiration is calmer and more equable. Thus in the tropics there is only one respiration and a fraction more in the evening; while in the temperate zone there is $1\frac{3}{4}$ nearly. Had the season been winter instead of summer, and the weather colder, the difference would have been greater.

II. *The Influence of Tropical Climates on the Pulse.*

Like the previously detailed experiments on the respiration, the present were made during a voyage from England (lat. 51° N.) to Bahia (lat. 11° S.) and back, *i. e.* across the equator, and extend over 60 days (53 in the tropics, and 7 in the latitude of England), during which the thermometer ranged from 57° to 84° F. (27° F.). The observations were taken thrice a day in the standing posture. Table VII. shows that, as in temperate latitudes*, the highest pulse of the day in the tropics occurs (though by no means invariably) in the morning.

TABLE VII.

Highest pulse of the day in the	{ 9 A.M. 20 days
tropics during 53 days	{ 3 P.M. 19 "
	{ 9 P.M. 14 "

* Dr. Guy, Guy's Hospital Reports, vol. iii.

The following Table shows, first, that the average pulse for the tropics ($87\frac{1}{2}$) is lower by $2\frac{1}{2}$ beats than that for the temperate zone (90), indicating a more languid circulation; second, that the same holds good for the average morning and evening pulse; third, that the average afternoon pulse is higher in the tropics than in temperate latitudes, probably from solar heat, greatest at that period of the day; fourth, that the highest and lowest pulse of the period occurs in the morning; fifth, that the morning pulse has the greatest, and the evening the lowest range.

TABLE VIII.—To contrast the tropical and temperate pulse &c.

	Number of observations.	Tropics.				Temperate zone average.
		Lowest.	Highest.	Range.	Average.	
9 A.M.	53	66	112	46	86.4	91.7
3 P.M.	53	68	108	42	88.8	88.1
9 P.M.	49	73	110	37	87.3	90.5
Averages					87.5	90.1

The reduction of the pulse in the tropics is doubtless related to the diminished respiratory function; and further observation may prove what the latter fact suggests, viz. that the pulse is diminished not only in frequency but in force*. The rise in the pulse towards afternoon and its subsequent fall are doubtless physiologically connected with a corresponding rise and fall in the temperature of the body at the same periods (Table IX.). The relation, however, does not extend to the volume or number of the respirations, the former being nearly alike during these three periods of the day, and the latter greatest towards night. As these observations, however, on the most excitable of all organs, the pulse, were made on one individual only, and at sea, where motion of the ship, weather, &c. render it impossible to ensure day by day the identical conditions necessary to give completely satisfactory results, their confirmation is necessary.

III. *The Influence of Tropical Climates on the Temperature of the Body.*

In this inquiry, so intimately connected with the two previous ones, viz. the respiration and circulation, the facts were ascertained by placing an ordinary Fahrenheit thermometer under the tongue thrice a day, during the same voyage as last, the temperature of the air in the shade on the verge of the tropics being 72° F., at the equator 84° F., and the average of the tropics generally 76.9 ; and the atmospheric humidity represented by a difference between the wet and dry bulbs of a Mason's hygrometer of 0° to $7\frac{1}{2}^{\circ}$, the average being $3^{\circ}.8$ F.

* Parkes ('Practical Hygiene') avers that the pulse is quicker in the tropics, though perhaps not so full. In animals moderate heat does not, but great heat does quicken the pulse. The latter, however, is evidently an unnatural temperature.

The following Table contrasts the average heat of the body in the tropics and in temperate climates. Thus, while in England during a summer and almost subtropical temperature ranging from 60° to 70° F., the average temperature of the body was 98°·3 F. it rose in the tropics to 98°·6, and in the equatorial doldrums to 99° F. The difference would have been greater had the season in England been winter, or the latitude higher. From column 3 it appears that the temperature of the body in the tropics is greatest during the afternoon, when the sun is high and the body most active, and least in the morning—an interesting fact in connexion with the pulse, likewise highest and lowest then.

TABLE IX.—To contrast the bodily temperature in tropical and extra-tropical latitudes.

	Temperate climate (near England), June, temp. 65° F., average of 10 days.	Tropics generally, average of 51 days,	Equator, temp. 84° F., average of 7 days.
9 A.M.	98·1	98·51	98·5
3 P.M.	98·3	99	99·5
9 P.M.	98·5	98·47	99·1
Average	98·3	98·66	99·02

While observation thus showed that the average temperature of the body about the latitude of England is 98°·3 F., the following Table shows that it rises in the tropics to 98½–99–99½, and occasionally even to 100° F. This fact is interesting, if not important, in connexion with temperatures in disease; and the mutual relation of the two is worth study.

TABLE X.—To show the temperature of the body in the tropics, and its relation to period of the day.

	Average temp. of air (shade).	Number of obser- vations.	Temp. 98° F.	Temp. 98½° F.	Temp. 99° F.	Temp. 99½° F.	Temp. 100° F.
9 A.M.	98·51	51	22	11	11	7	0
3 P.M.	99	51	6	5	18	17	5
9 P.M.	98·47	51	8	23	15	5	0
Averages and totals	98	153	36	39	44	29	5

Table X. further shows the great preponderance of the lower temperatures, especially the lowest (98° F.), during the mornings, of the higher during afternoon, and of the medium ones (98½° and 99° F.) during the evening. The heat of the body (and the blood?) thus rises in the

tropics with the temperature of the air, and probably the activity of the body and brain, both greatest in the afternoon, and again decrease with these towards evening. The highest temperature (100°) occurred at 3 P.M., the most oppressive part of the day in the equatorial calms, where the air was most stagnant, humid, and hot (81° to 84° F.), with no breeze to cool, by carrying off the surface heat, and facilitating evaporation. Their source could not be dietetic, as little food was taken between 8 A.M. and 6 P.M., and there was no rise after the latter hour. For the same reason it could not be the result of local muscular activity. The totals show that 99° was the most frequent temperature, and next to it $98\frac{1}{2}^{\circ}$, while $99\frac{1}{2}^{\circ}$ and 100° form no less than 22 per cent. of the whole. Is not the blood itself likewise somewhat warmer in tropical than in extra-tropical latitudes? The range of the temperature of the body in health is thus about 2° F. John Davy gives it as from $\cdot 5$ to 1° F.*; Eydaux and Brown Sequard at from 1° to $2\frac{1}{2}^{\circ}$ and 3° F. The super-oceanic atmosphere, in which the present observations were made, is never so highly saturated as to completely stop evaporation from the cutaneous surface, otherwise the temperature of the latter would rise much higher. Blagden and Fordyce bore a temperature of 260° in the dry air of a heated oven, the temperature of their skin rising $2\frac{1}{2}^{\circ}$ F. only; but when the air of the heated oven is so moist as to hinder evaporation, the temperature of the body rises rapidly; Ludwig says as much as 7° or 8° F., and Obernier confirms this†. Observations on this point are still wanted with regard to continental, littoral, and insular equatorial climates, both dry and humid.

The following Table, which shows the relation of the temperature of the body to that of the external air in the shade, indicates a gradual though trivial increase in the temperature of the former with that of the temperature of the latter, proving that the one is slightly influenced by the other. Thus at first it was 98° F.; then $98\cdot 3$, $98\cdot 6$, $98\cdot 63$, $98\cdot 8$, $99\cdot 08$ successively, as the temperature of the air rose from 57° F. to 84° F., the average for the warmest part of the temperate zone being $98\cdot 3$, and for the tropics somewhat more, viz. $98\cdot 836$. The Table further shows that 98° F. is the prevalent temperature of the body in the temperate zone, as it occurred in 24 out of 37 markings; while in the tropics 99° F. is the most frequent, and $98\frac{1}{2}^{\circ}$ and $99\frac{1}{2}^{\circ}$ nearly as frequent. These results correspond closely with those of Dr. Davy‡.

* Parkes, 'Practical Hygiene.'

† Ibid.

‡ As quoted by Carpenter ('Physiology').

TABLE XI.—To show the relation of temperature of the body to that of the air in the shade, especially in the tropics.

	Temperate Zone. Temperature of air between			Tropics. Temperature of air between					
	57° & 60°.	60° & 65°.	65° & 70°.	70° & 75°.	75° & 80°.	80° & 84°.			
Highest	98 ⁰	99 ⁰	99½ ⁰	100 ⁰	100 ⁰	100 ⁰			
Lowest	98	98	98	98	98	98			
Range.....	0	1	1½	2	2	2			
Averages	98	98·3	98·6	98·63	98·8	99·08			
Total averages		98·3			98·836				
Number of markings of temperature of body, taken thrice a day, viz. at 9 A.M., 3 P.M., and 9 P.M.	98°	7	6	9	22	20	18	6	44
	98½°	...	1	1	2	4	37	3	44
	99°	...	2	6	8	18	32	6	56
	99½°	...	...	3	3	4	23	12	39
	100°	...	...	...	...	2	1	4	7
			Total		35		Total		190

Unfortunately the statistics were not sufficiently numerous to draw satisfactory deductions as to the effect of humidity on the temperature of the body in mid-ocean in the tropics, where the amount of moisture is usually considerable. This would be interesting, as would others regarding tropical terrestrial climates, in some of which the hygrometric range is sometimes smaller, though in the majority greater.

V. "Observations on the Mode of Growth of Discoid and Turbinated Shells." By ALEXANDER MACALISTER, Professor of Zoology, University of Dublin. Communicated by the Rev. S. HAUGHTON, F.R.S. Received May 4, 1870.

A most interesting paper on the geometrical forms of turbinated and discoid shells was published by the Rev. Canon Moseley in the Philosophical Transactions for 1838, p. 351, in which some important points were noticed regarding the geometrical construction of shell-forms. The author of that paper describes discoid shells as generated by the revolution around a central point of the perimeter of a geometrical figure, which latter, although regularly increasing in size, yet remains always geometrically similar in form. The producing figure in many Gasteropodous Mollusks is represented by the operculum, and in all it may be recognized by making a vertical section in the plane of the radius vector. A turbinated shell is similarly generated, but the generating figure in the production of the helix slips down along the axis instead of revolving in a constant plane. The Rev. Mr. Moseley gives, as illustrations of these points, measurements of *Nautilus pompilius*, *Turbo phasianus*, *Turbo duplicatus*, and